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(54) **Liquid level gauge**

(57) An ultrasonic liquid level gauge 10 comprises two solid surfaces 42 and 50 in opposed relationship, and a plane reflecting surface 32 supported between the surfaces so as to be slightly below the liquid level 18 in use. A Lamb wave is caused to propagate down one surface 42, undergoing mode conversion to compression waves in the liquid 16 which reflect off the reflecting surface 32 onto the other surface 50, undergoing mode conversion to a Lamb wave propagating up the other surface 50.

The reflecting surface 32 may be supported by a float 30, and the solid surfaces 42 and 50 may be opposite walls of a rectangular tube 12.

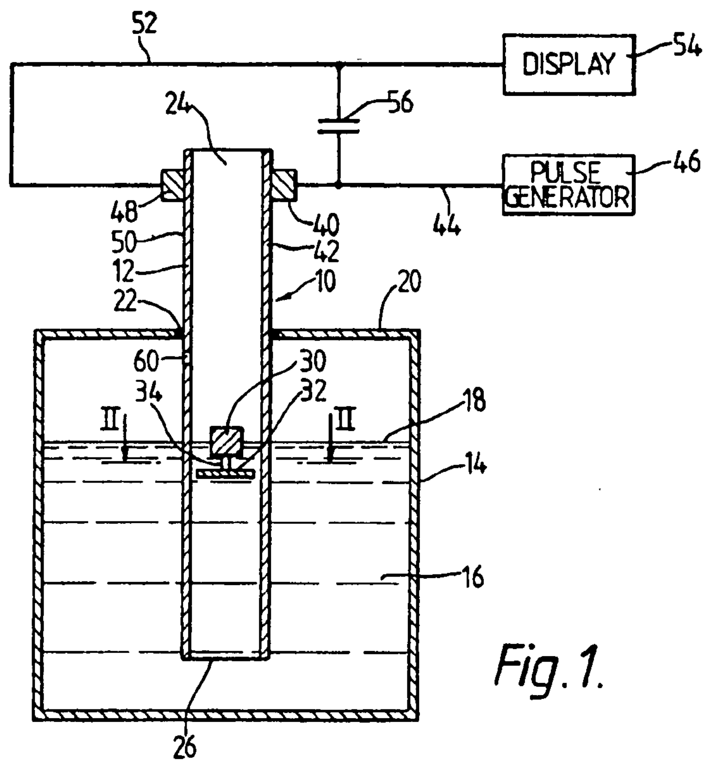

Fig. 1.

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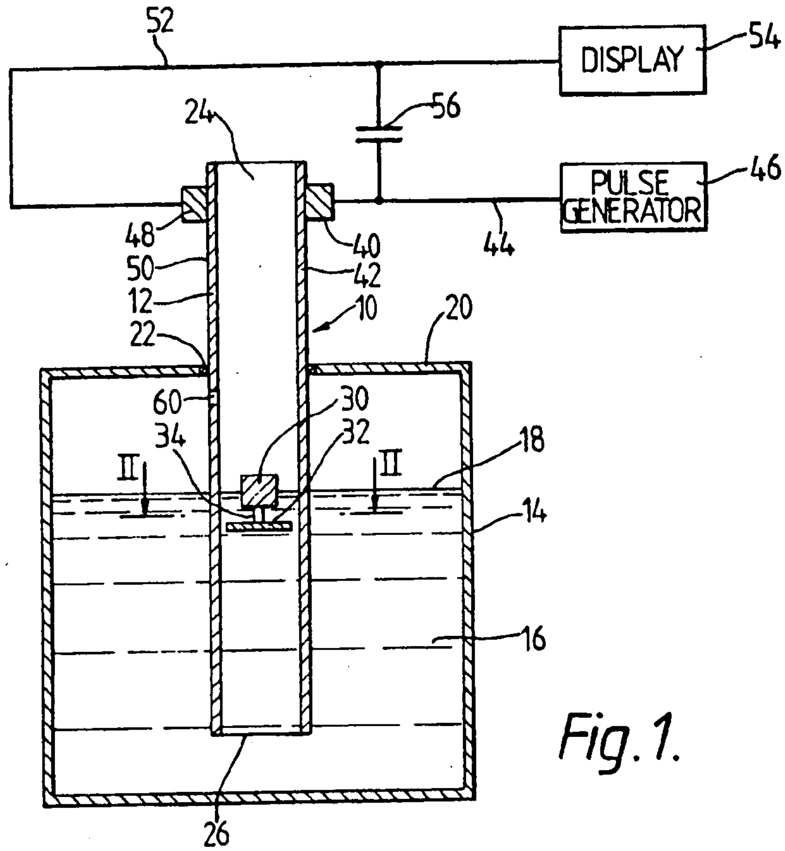

Fig. 1.

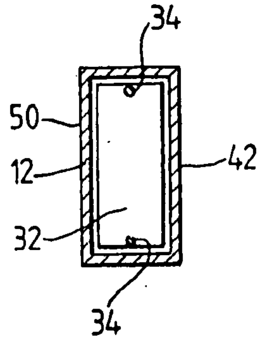

Fig. 2.

SPECIFICATION

Liquid Level Gauge

This invention relates to a liquid level gauge, which may for example be installed within a liquid storage tank or dipped into such a tank, to provide an indication of the level of the liquid, and in particular relates to a liquid level gauge utilizing ultrasonic waves.

British Patent No. 2 019 568B describes an ultrasonic liquid level gauge comprising a solid surface immersible in a liquid, means for exciting surface acoustic waves in the solid surface, the surface acoustic waves undergoing mode conversion in the liquid to form compression waves, and a reflector to reflect the compression waves so formed back to the solid surface. The reflector comprises a plurality of individual planar reflecting elements positioned adjacent to the solid surface so as to be successively exposed as the liquid level falls. The direction of propagation of the compression waves so produced by mode conversion depends on the relative speeds of the compression waves in the liquid and of the surface acoustic waves in the solid, and so the inclination of the reflecting elements must be set to the angle appropriate for a particular liquid.

According to the present invention there is provided a liquid level gauge comprising two solid surfaces extending in opposed relationship to each other, and arranged so as to be at least partly immersible in a liquid the position of whose surface is to be determined, a transmitter arranged to cause surface acoustic waves to propagate down one of the solid surfaces, a receiver arranged to receive surface acoustic waves propagating up the other solid surface, a plane reflecting surface located between the two solid surfaces so as in use, for at least one position of the liquid surface, to lie a short distance below the liquid surface and to reflect compression waves formed by mode conversion of the surface acoustic waves in the one solid surface onto the other solid surface so as to generate surface acoustic waves in the other solid surface by mode conversion, and means for determining from the waves received by the receiver the position of the liquid surface.

A plurality of plane reflecting surfaces may be provided spaced apart along the solid surfaces. Alternatively a single plane reflecting surface may be provided, supported by a float so as to remain the said short distance below the surface. The surface acoustic waves are preferably Lamb waves. In a preferred embodiment the two solid surfaces are defined by opposite walls of a tube of rectangular cross-section.

The liquid level gauge of the invention can be used without any adjustment in almost any liquid. Also, since the transmitter and the receiver are coupled to different surfaces, acoustic noise due to transmitter/receiver coupling is minimised.

The invention will now be described by way of example only and with reference to the accompanying drawings, in which:-

Figure 1 shows a diagrammatic sectional view, in a vertical plane, of a liquid level gauge installed in a tank; and

Figure 2 shows a view on the line II-II of Fig. 1.

Referring to Figs. 1 and 2, a liquid level gauge 10 comprises a stainless-steel, rectangular cross-section section tube 12, which extends downwards into a tank 14 so as to be partly immersed in a liquid 16 therein, the position of whose surface 18 is to be determined. The tube 12 passes through the top 20 of the tank 14, being supported by a rubber seal 22, and is open at its upper end 24 and its lower end 26. Within the tube 12 is a float 30 supporting a rectangular, horizontal, flat, reflector plate 32 by means of two vertical struts 34, one at each end of the plate 32, so that the plate 32 is supported a short distance below the surface 18 of the liquid 16 within the tube 12.

A transmitter transducer 40 is attached to one broad wall 42 of the tube 12 near the upper end 24, and is connected by a lead 44 to a pulse generator 46. A receiver transducer 48 is attached to the opposite broad wall 50 of the tube 12 near the upper end 24, and is connected by a lead 52 to a signal analyser and display 54, the lead 52 being connected through a coupling capacitor 56 to the lead 44. A small hole 60 is provided through the broad wall 50 of the tube 12 below the top 22 of the tank 14, above the highest level to which the surface 18 is expected to rise, which ensures equality of pressure above the liquid 16 both inside and outside the tube 12 and consequently ensures that the surface 18 is at the same level inside and outside the tube 12. In addition the hole 60 may be used for calibrating the gauge 10.

In operation of the gauge 10, the pulse generator 46 is energised to cause the transmitter transducer 40 to generate a pulse of Lamb waves, which propagate down the broad wall 42 of the tube 12. Mode conversion takes place below the surface 18, within a few wavelengths of the surface 18, generating plane compression waves in the liquid 16. The compression waves are reflected specularly by the reflector plate 32. Consequently, at the opposite wall 50 they undergo mode conversion to generate Lamb waves which propagate up to the receiver transducer 48.

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The signal analyser and display 54 thus receives an initial signal (through the capacitor 56) when the pulse of waves is transmitted, and a return signal (from the receiver transducer 48) when the pulse of waves returns, and from the time interval between these signals the distance from the transducers 40, 48 to the surface 18 is determined and is displayed.

Furthermore, owing to the coupling capacitor 56, some of the energy from the pulse generator 46 causes the receiver transducer 48 to generate a pulse of Lamb waves simultaneous with the Lamb wave pulse generated by the transmitter transducer 40 but of smaller energy. This low energy pulse does not affect the operation of the gauge 10 as described above, but will be reflected by the small hole 60 to produce an echo signal at the receiver transducer 48, which may be used for calibration of the gauge 10.

It will be appreciated that the time interval between the initial signal and the return signal depends upon not only the distance between the tranducers 40, 48 and the surface 18, but also the time taken to propagate as a compression wave between the wall 42 and the opposite wall 50. This may be taken into account, as the additional time is given by T, where:

$$T = \frac{1}{v}\left[D + \frac{x}{2\cos\theta}\left[\frac{v}{u} - \frac{u}{w}\right]\right]$$

in which

D = distance of the plate 32 below the surface 18
x = width of the tube 12 between the wall 42 and the wall 50
u = velocity of compression waves in the liquid 16
v = group velocity of Lamb waves
w = phase velocity of Lamb waves, and
θ = arcsin (u/w)

The liquid level gauge 10 will thus operate effectively with almost any liquid 16, though as the additional time T depends on the nature of the liquid 16 the zero of the display 54 might be adjusted for different liquids. The Lamb waves do not tend to propagate around the corners of the tube 12 so very little acoustic background noise is received by the receiver transducer 48. It will be appreciated that free movement of the float 30 and the reflector plate 32 is essential to accurate operation of the gauge 10, and so the gauge 10 is not suitable for use with very viscous liquids.

It will be appreciated that where a continuous indication of the liquid level is not required, the float 30 and the reflector plate 32 may be replaced with a number of reflector plates 32 spaced out along the tube 32 and supported clear of the walls by a support rod (not shown). For example, plates 32 might be located slightly below the lowest and the highest liquid levels expected, so that when the liquid surface 18 is a short distance above one or the other of these plates 32, a return signal will be received.

It will also be appreciated that the tube 12 might be replaced by two solid surfaces in opposed relationship (equivalent to the walls 42 and 50) spaced apart by struts (not shown).

CLAIMS

1. A liquid level gauge comprising two solid surfaces extending in opposed relationship to each other, and arranged so as to be at least partly immersible in a liquid the position of whose surface is to be determined, a transmitter arranged to cause surface acoustic waves to propagate down one of the solid surfaces, a receiver arranged to receive surface acoustic waves propagating up the other solid surface, a plane reflecting surface located between the two solid surfaces so as in use, for at least one position of the liquid surface, to lie a short distance below the liquid surface and to reflect compression waves formed by mode conversion of the surface acoustic waves in the one solid surface onto the other solid surface so as to generate surface acoustic waves in the other solid surface by mode conversion, and means for determining from the waves received by the receiver the position of the liquid surface.

2. A liquid level gauge as claimed in Claim 1 wherein a plurality of plane reflecting surfaces are provided, spaced apart along the solid surfaces and fixed relative to the solid surfaces.

3. A liquid level gauge as claimed in Claim 1 including a single plane reflecting surface supported by a float so as to remain at the said short distance below the surface.

4. A liquid level gauge as claimed in any one of the preceding Claims wherein the two solid surfaces are defined by opposite walls of a tube of rectangular cross section.

5. A liquid level gauge substantially as hereinbefore described with reference to, and as shown in, Figs. 1 and 2 of the accompanying drawings.

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